Update on Fluorescence:

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At the last Meeting:

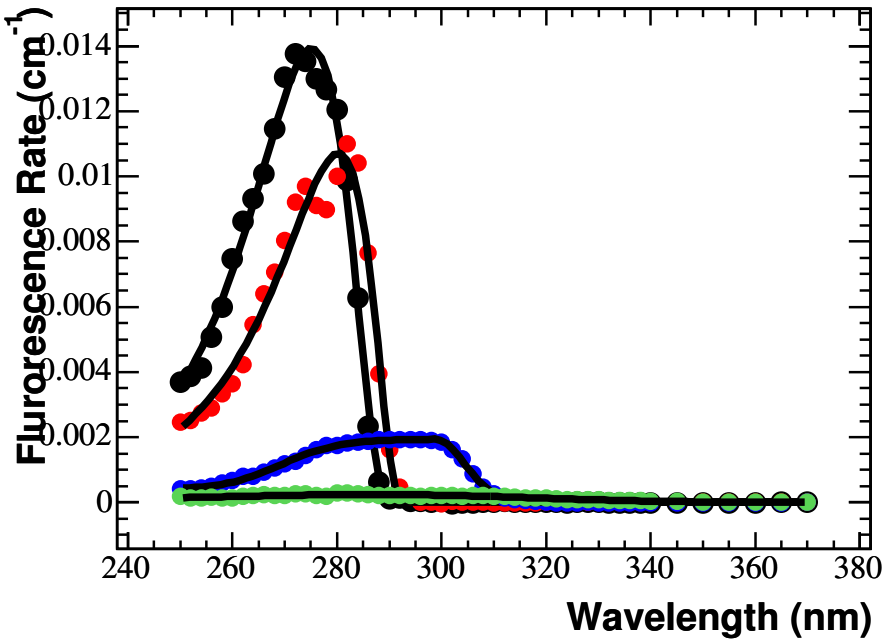
Bruce reported that Dmitri has finished SVD analysis:

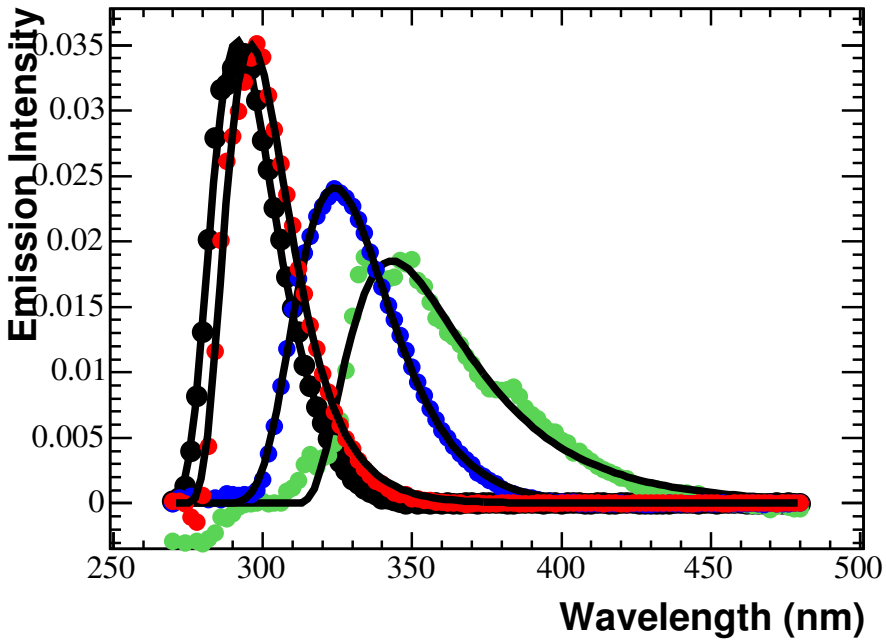
- Documented in JHU Report No. 7
- Linear algebra technique (singular value decomposition) determines features with characteristic excitation and emission curves.
- Very complicated and sophisticated analysis

Basic results:

- Analysis covers excitation from 250-380 nm
- Analysis covers emission from 270-480 nm
- Four signficant features found: excitation and emission curves determined for each.
- Absolutely normalized fluorescence rate/photon/pathlength

Results of SVD analysis

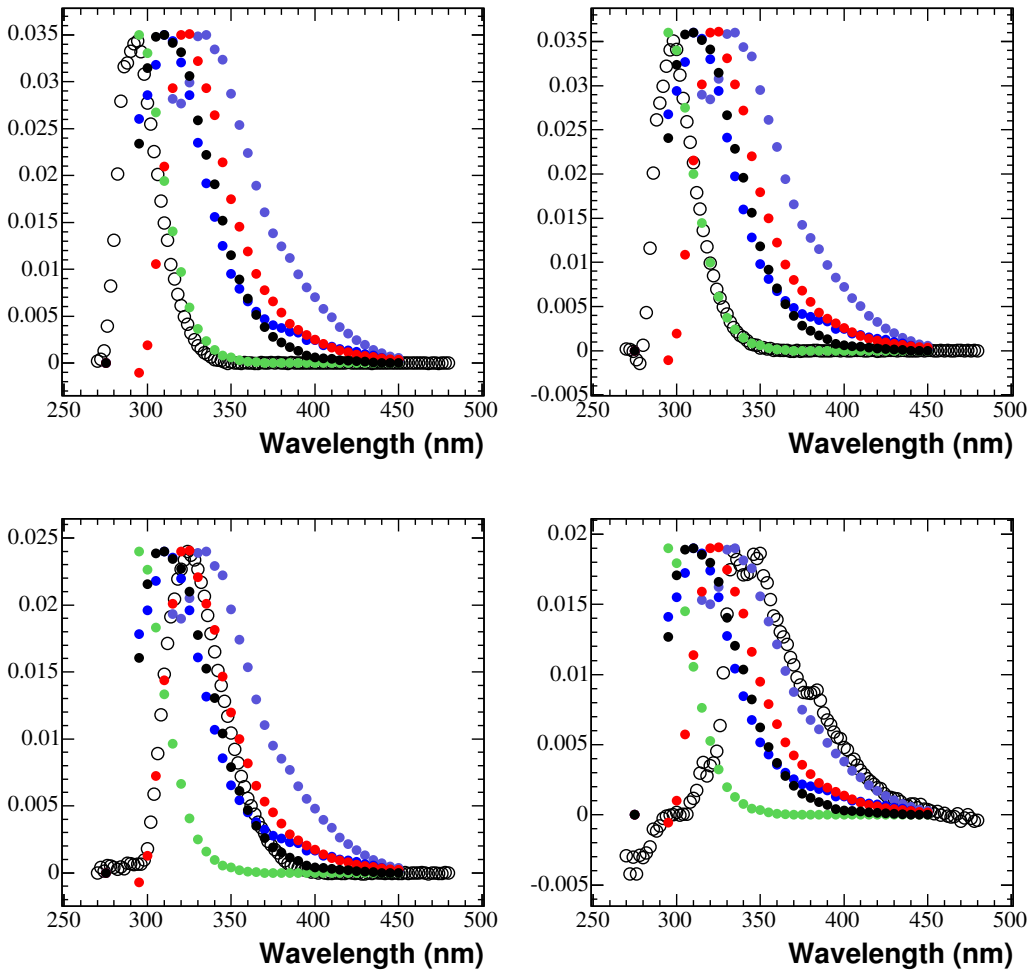




Things to investigate:

- We need to assign a lifetime to each system:
  Compare emission with time-resolved measurements and match
- Compare with existing data for compatibility:
  predict emission/excitation curves and compare with measurements

Assigning Lifetimes



open circles: emission from SVD
solid circles: emission from t-resolved

SVD Feature 1:

- Matches best with green
  But does not match well

SVD Feature 2:

- Matches best with green
  matches very well

SVD Feature 3:

- Matches best with red
  Except for tail

SVD Feature 4:

- Matches best with black

Results from Assigning Lifetimes

- SVD Feature 1:
  Does not match any of the fluorophores:
  This is expected: the excitation curve falls to zero around 280 nm
  Time-resolved measurement occurs at 285 nm: feature was not excited
- SVD Feature 2
  Matches green very well: 14 ns lifetime
- SVD Feature 3: Roughly matches blue curve (Vitamin E fluorophore):
  The emission/excitation has been obtained in steady-state meaurements:
  Disagreement between steady-state/t-resolved measurement
  Nonethless, assign 1 ns lifetime.
- SVD Feature 4: Mathches black curve. Assign 33 ns lifetime.

Others may be too weak to be identified by SVD analysis
One fluorophore (the strongest!) is left without a lifetime.

Inclusive versus Exclusive

With the SVD results, we can predict:

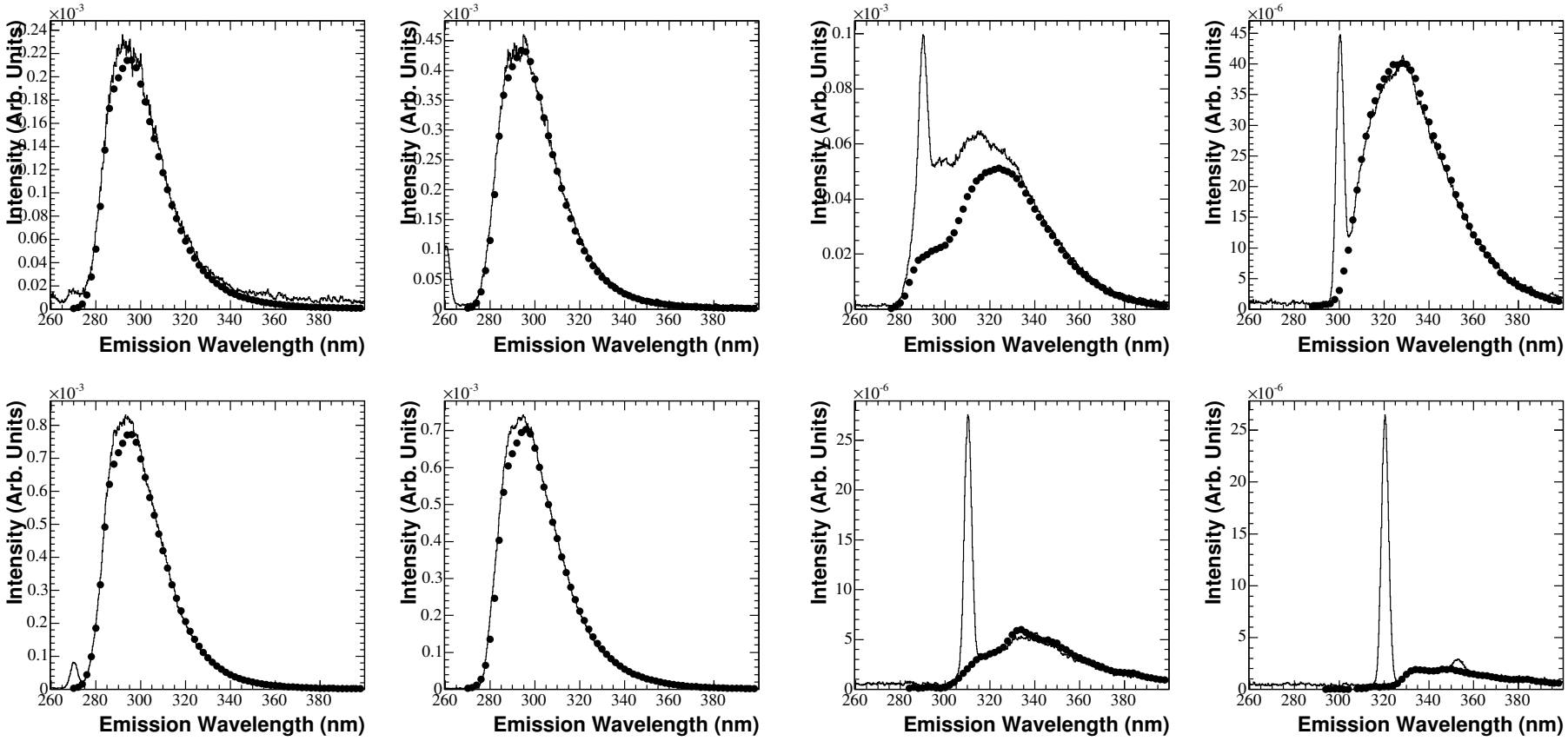
- For a given input wavelength, the contribution from each fluorophore
  Output spectrum should be weighted sum of emission from each fluorophore
  $\longrightarrow$ emission curve

- For a given output wavelength, the contribution from each flurophore
  Input response should be weighted sum of excitation from each flurophore
  $\longrightarrow$ excitation curve

Sum of exclusive (SVD) should equal inclusive (ex/em curve):

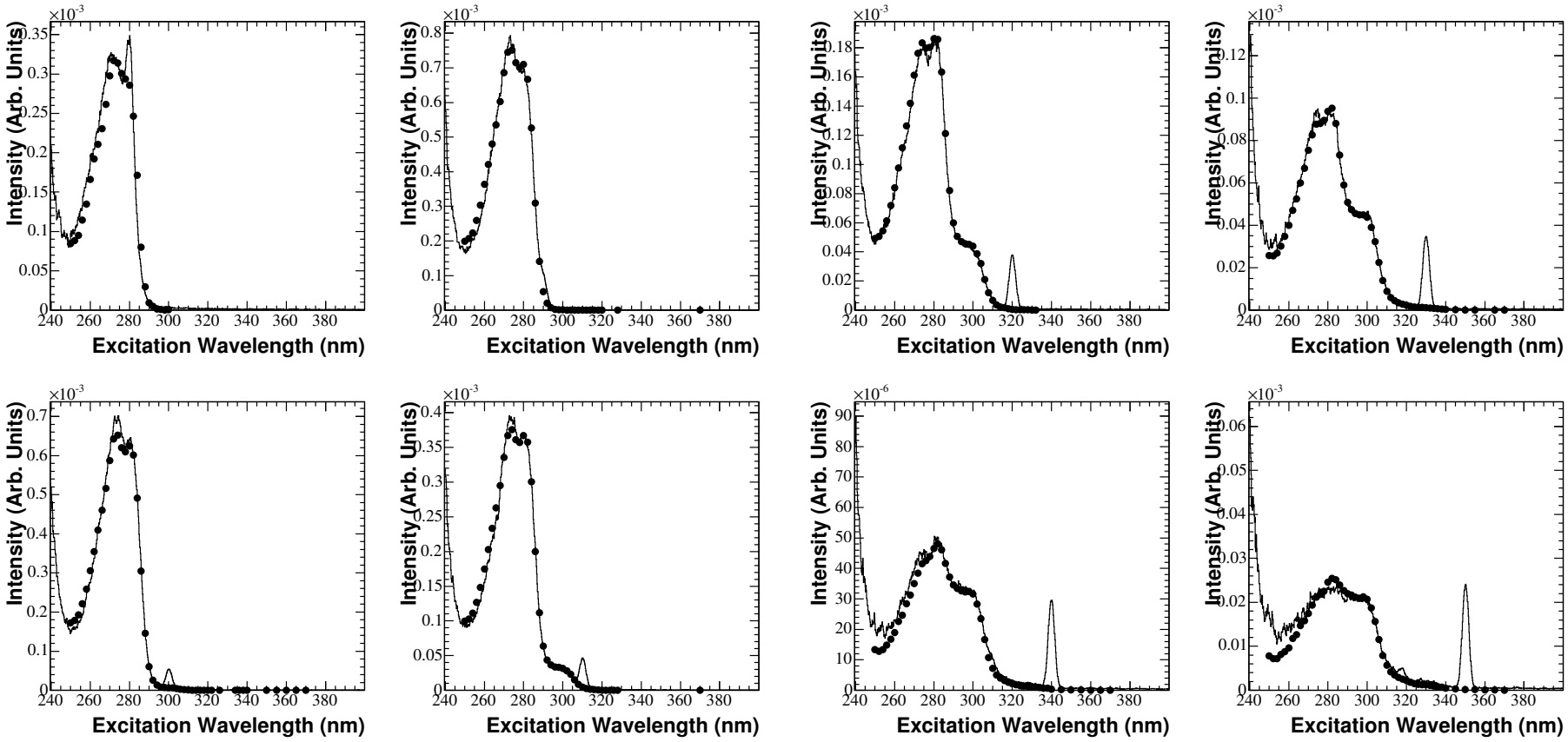
Compare the predicted inclusive curves with independent measurements
(courtesy of Anna Pla/Shannon Maza)

Emission Curves



250-320 nm emission curves (solid), SVD prediction (dots)
Good agreement except at 280 nm

Excitation Curves



280-350 nm excitation curves (solid), SVD prediction (dots)
This is very encouraging:
Many corrections (lamp strength, inner filter, detection efficiency, etc.) go into making these curves.
Agreement means that these are being handled consistently.

Toy MC Studies

A number of questions need to be answered:

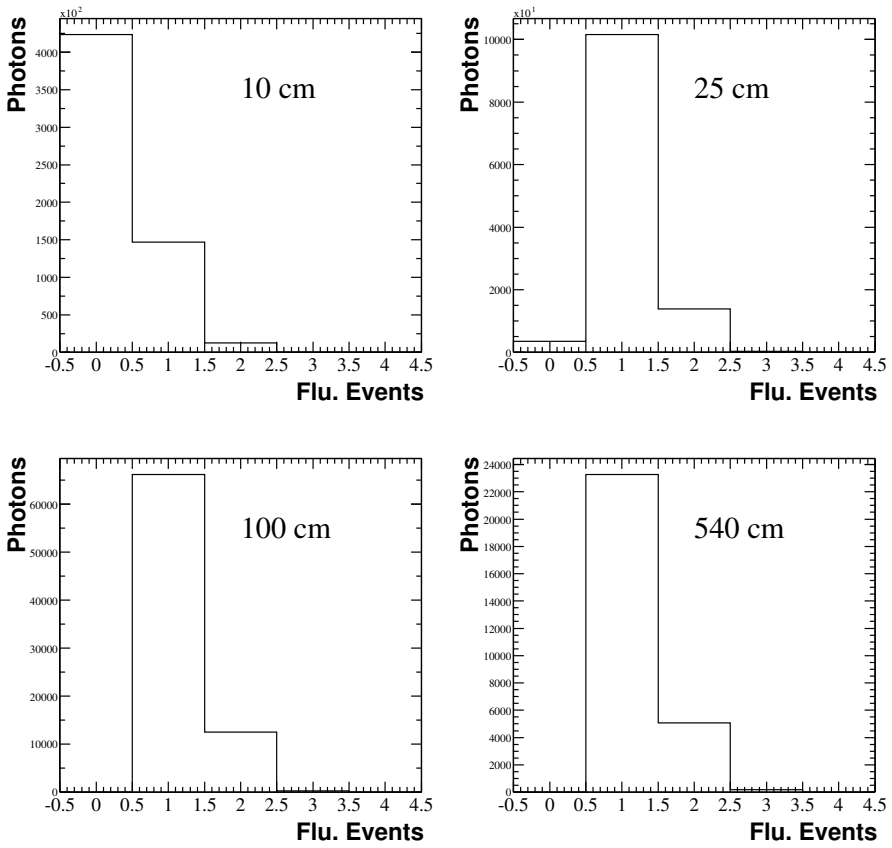
- Which, if any, of the fluorescence processes are important?
- Do we need to worry about multiple fluorescence?
- How does the fluorescence appear in the detector (time/wavelength)? How is affected by other processes, such as scattering?
- Is there a simple "effective" model that is good enough for us?

A simple photon-transport simulation has been developed:
Simulates some of the processes identifed thus far:

- Absorption
- Scattering
- 3 fluorescence processes (1, 14, 33 ns lifetimes)

Unidentified fluorophore with unknown liftime is left out for now.

Fluorescence Rate:



Generate photons at $r = 0$, $\lambda = 270$ nm
Observe at $R = 10,\ 25,\ 100,\ 540$ cm

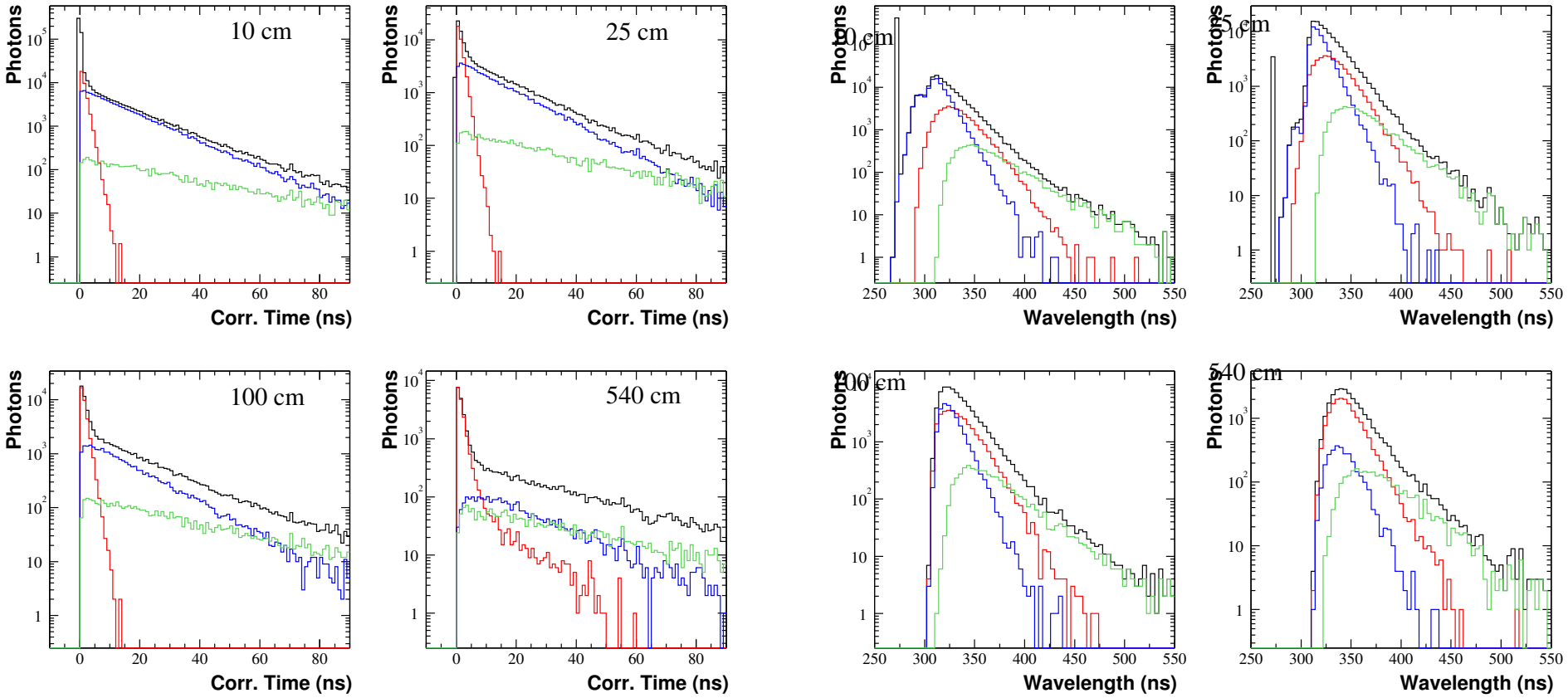
Study 270 nm source

- At 10 cm:
  Some direct light observed
- At 25 cm:
  Almost all of it fluoresces
- Significant multiple fluorescence
  25% relative to single

Multiple Fluoresce results in:

- Complicated time structure
  Non-exponential
- λ_f of last fluorophore
  Doesn't "remember" prior events

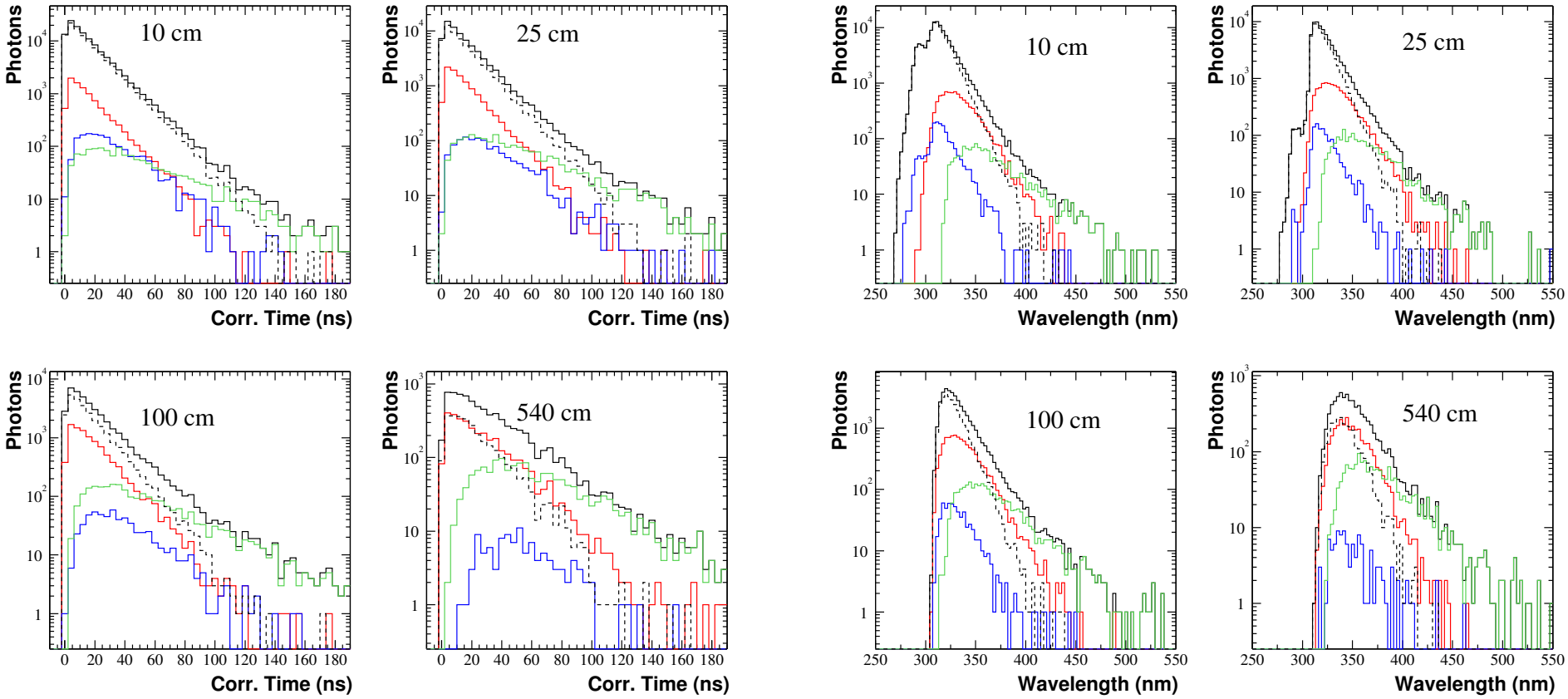
Evolution of Fluorescence Light:



(black/red/blue/green = all/1 ns/14 ns/33 ns)

- 14 ns fluorophore (blue) is supressed as we move away from source
- 1 ns (red) becomes strong and 33 ns (green) comparable in strength to 14 ns

Multiple Fluorescence via 14 ns system:



(black/red/blue/green = all/1 ns/14 ns/33 ns)

- Fluorescing 1 ns (red) doesn't change things much
- Fluorescing 33 ns (green) results in very complicated time structure

Summary

- JHU SVD analysis is consistent with Fermilab meausurements
- Some of the fluorphores (0.35, 6 ns) may be insignifcant
- We do not know the lifetime of the strongest fluorophore
- Excitation behavior < 250 nm (where most of it occurs) is unknown.
  We are attempting an SVD analysis on the Fermilab data (Vassilios)
- Studies of multiple fluorophore systems started:
  Multiple fluorescence is expected
  Time structure is complicated: can we hope for a simple model?